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(54) **ANTENNA AND WIRELESS IC DEVICE**

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See application file for complete search history.

(75) Inventors: **Noboru Kato**, Nagaokakyo (JP); **Jun Sasaki**, Nagaokakyo (JP); **Teppe Miura**, Nagaokakyo (JP); **Naoki Gouchi**, Nagaokakyo (JP)

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(73) Assignee: **Murata Manufacturing Co., Ltd.**,
Kyoto (JP)

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Primary Examiner — Robert Karacsony

Assistant Examiner — Amal Patel

(74) *Attorney, Agent, or Firm* — Keating & Bennett, LLP

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(57) **ABSTRACT**

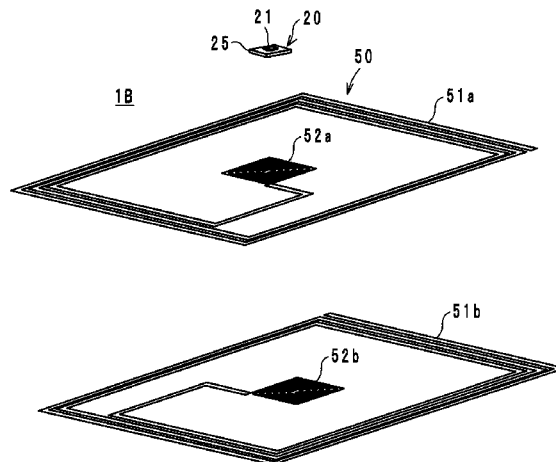
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An antenna for a wireless IC device having improved energy transfer efficiency with a wireless IC, and a wireless IC device equipped with the antenna are constructed such that the antenna includes a coil pattern and spiral coupling patterns provided at the ends of the coil pattern and disposed so as to face each other. A coupling module including a wireless IC chip and a feeder circuit substrate including a feeder circuit arranged to be coupled to the wireless IC chip is mounted on the coupling pattern so as to define a wireless IC device. The coil pattern is an open type coil pattern. The coupling patterns are arranged close to each other to define a single LC resonator. Thus, energy is concentrated in the coupling patterns, thereby improving the energy transfer efficiency between the antenna and the wireless IC chip.

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(58) **Field of Classification Search**
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8 Claims, 11 Drawing Sheets



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FIG. 1

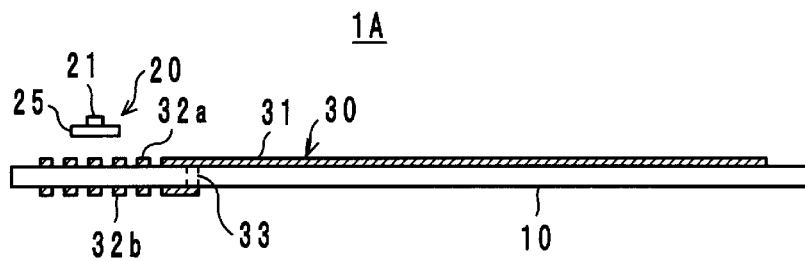


FIG. 2

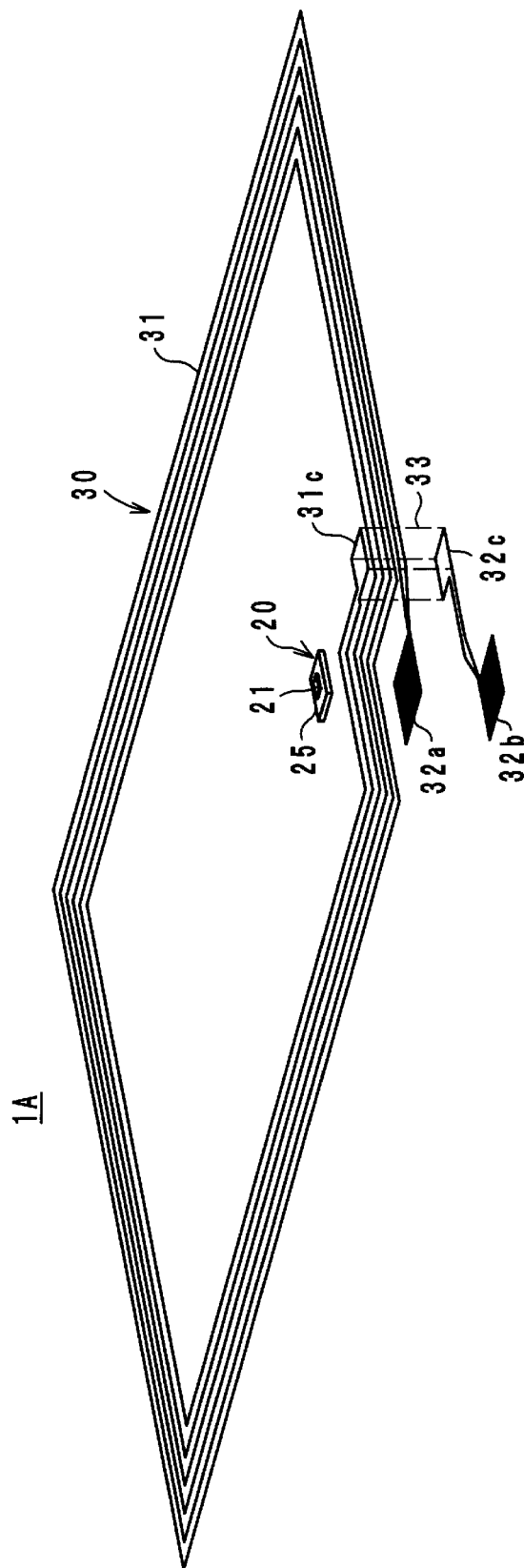


FIG. 3

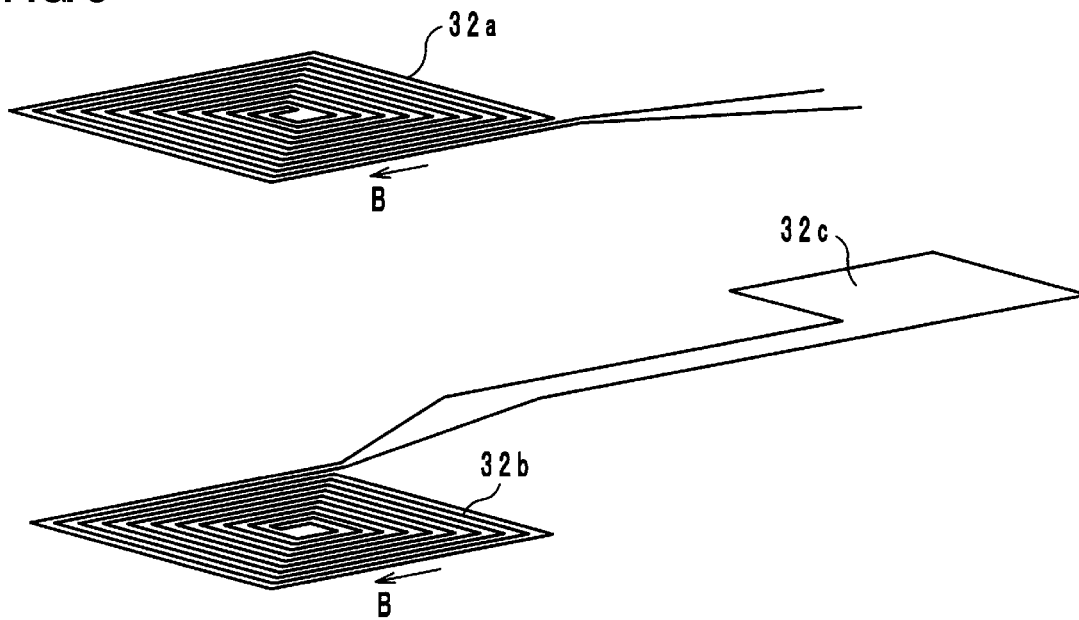


FIG. 4

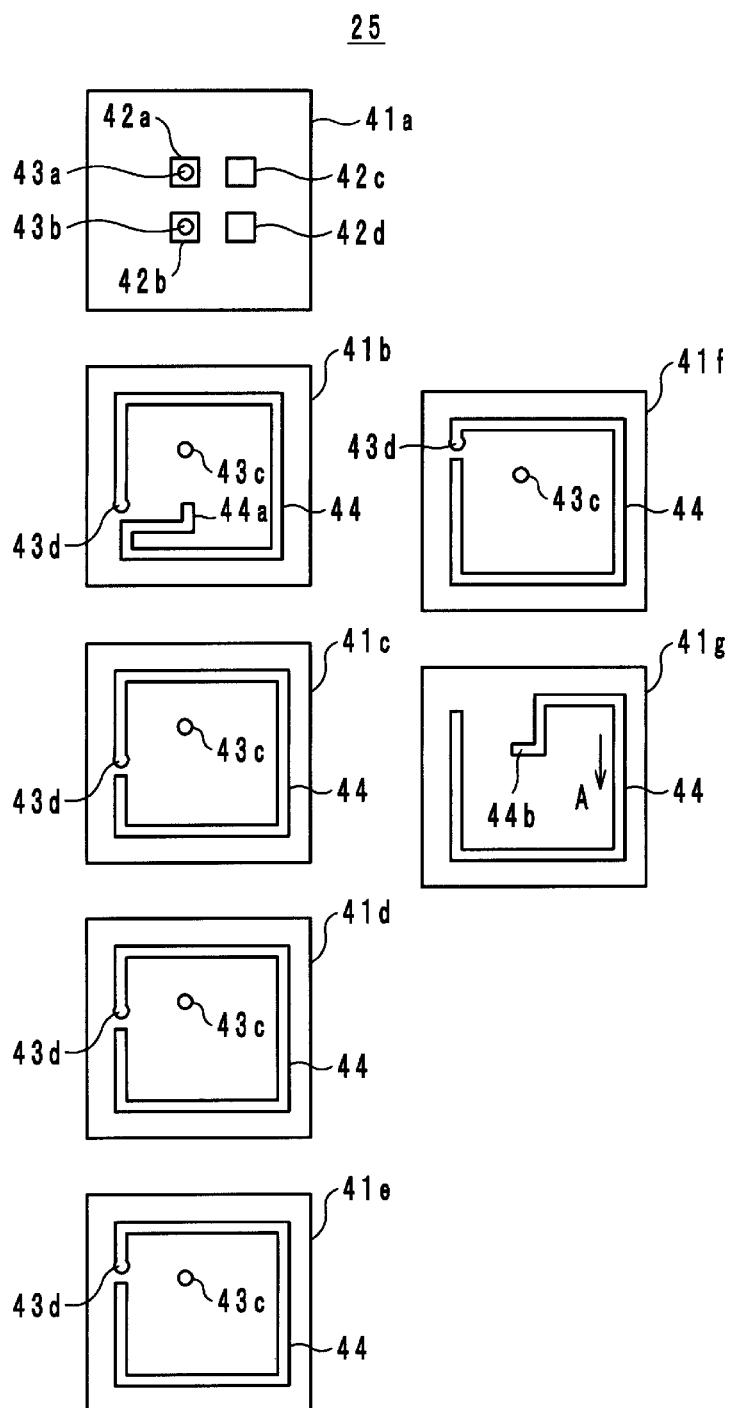


FIG. 5

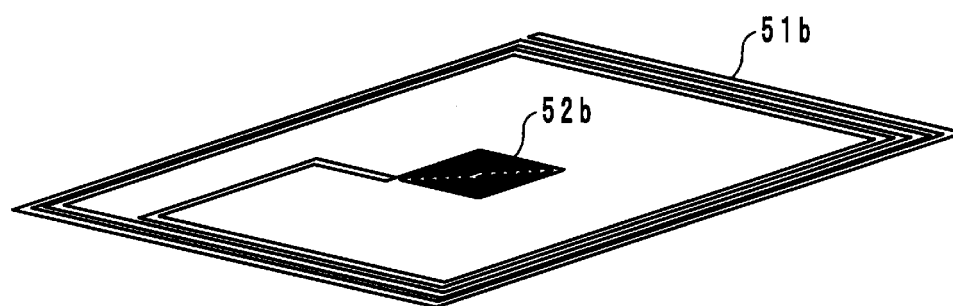
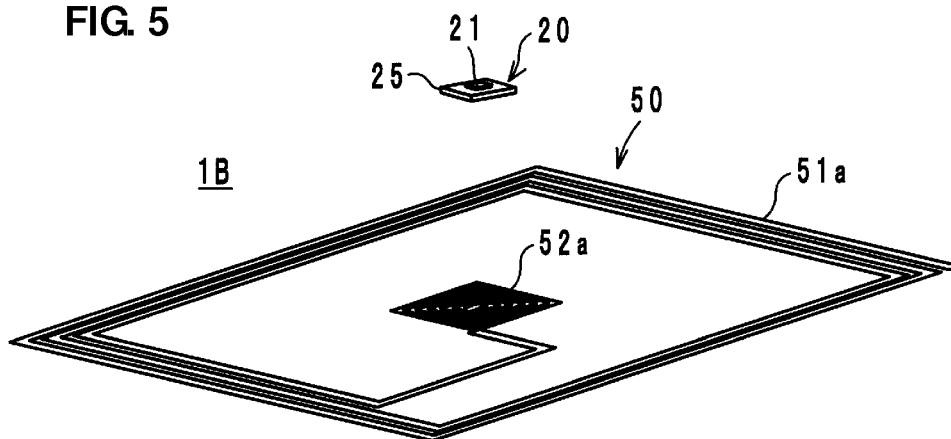


FIG. 6

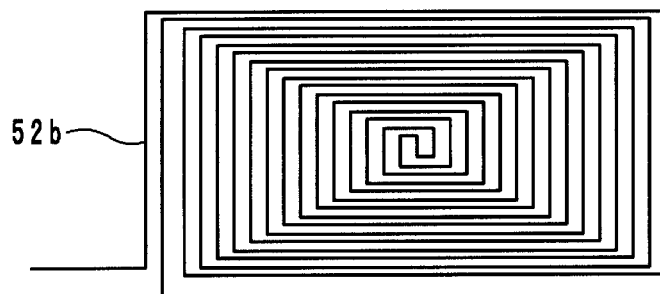
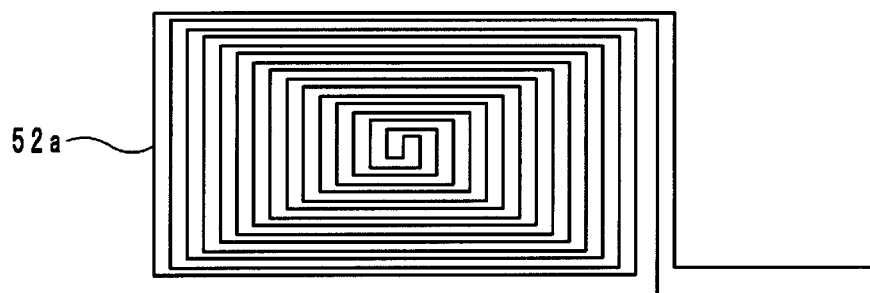


FIG. 7

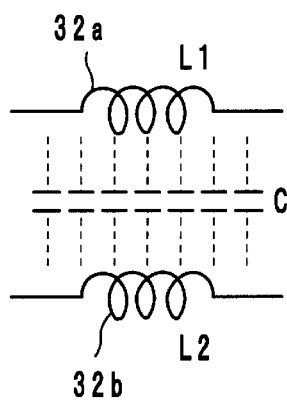


FIG. 8

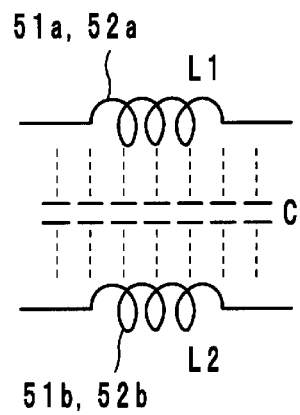
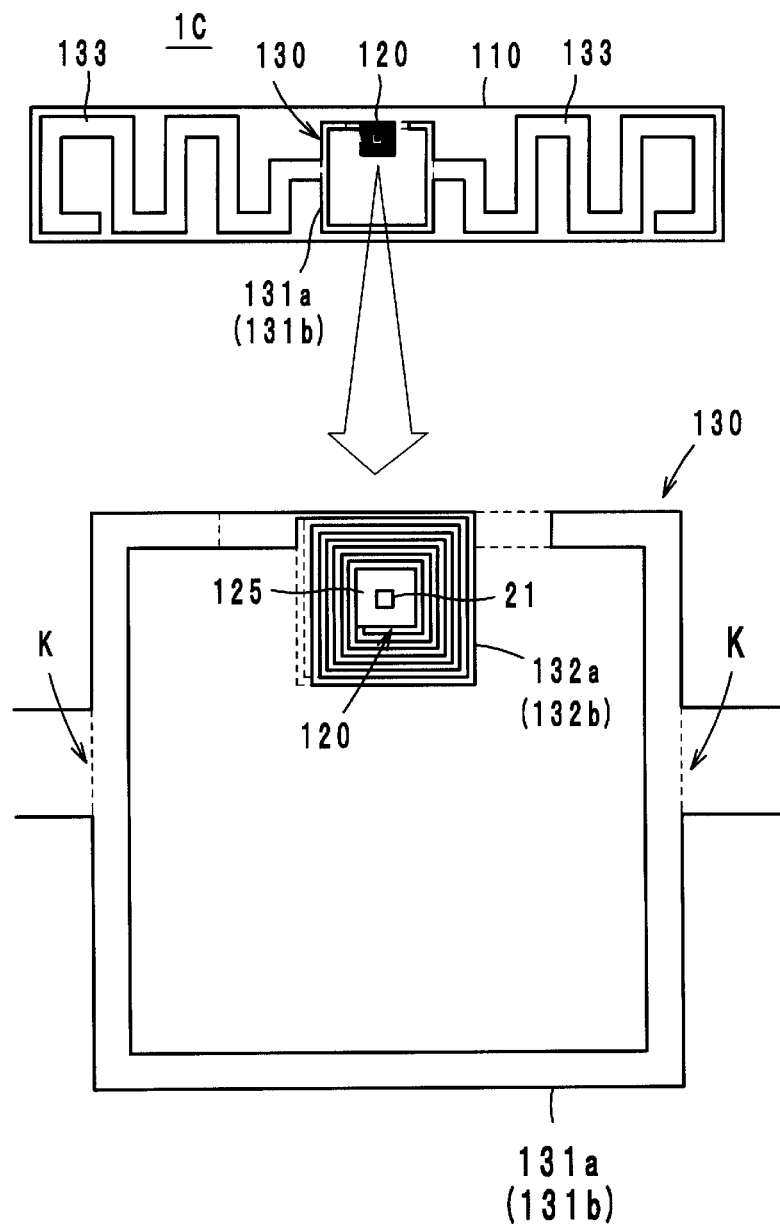
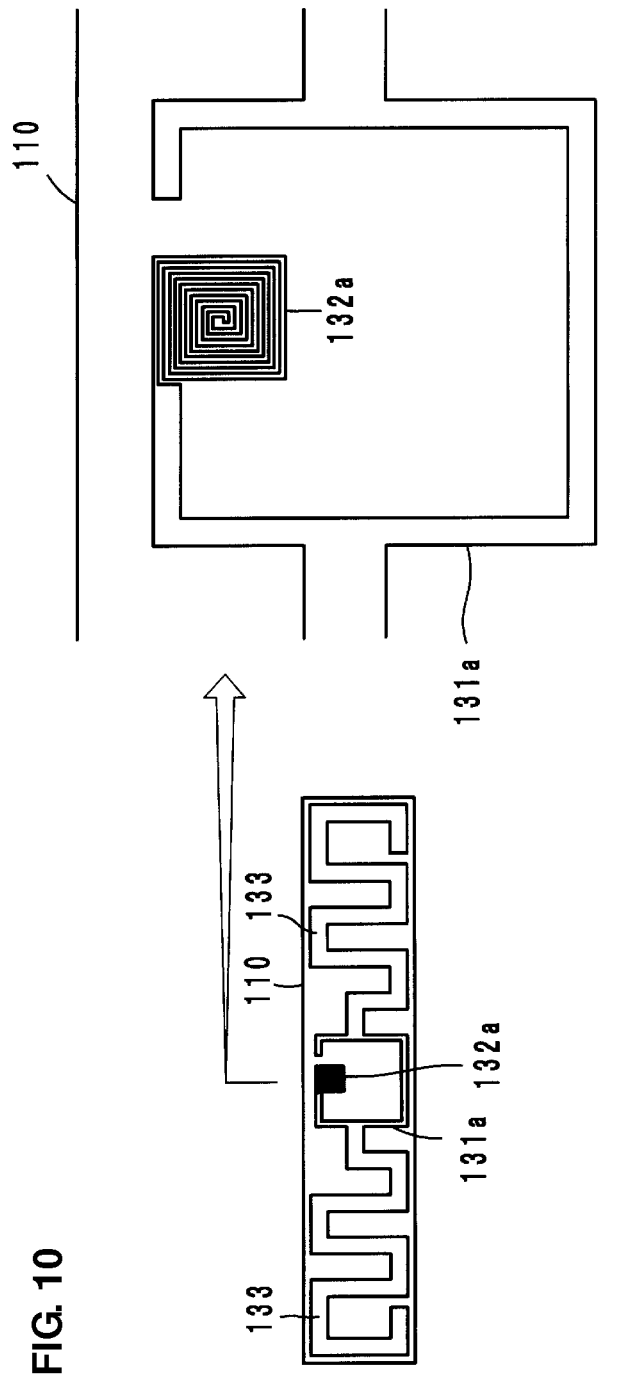


FIG. 9





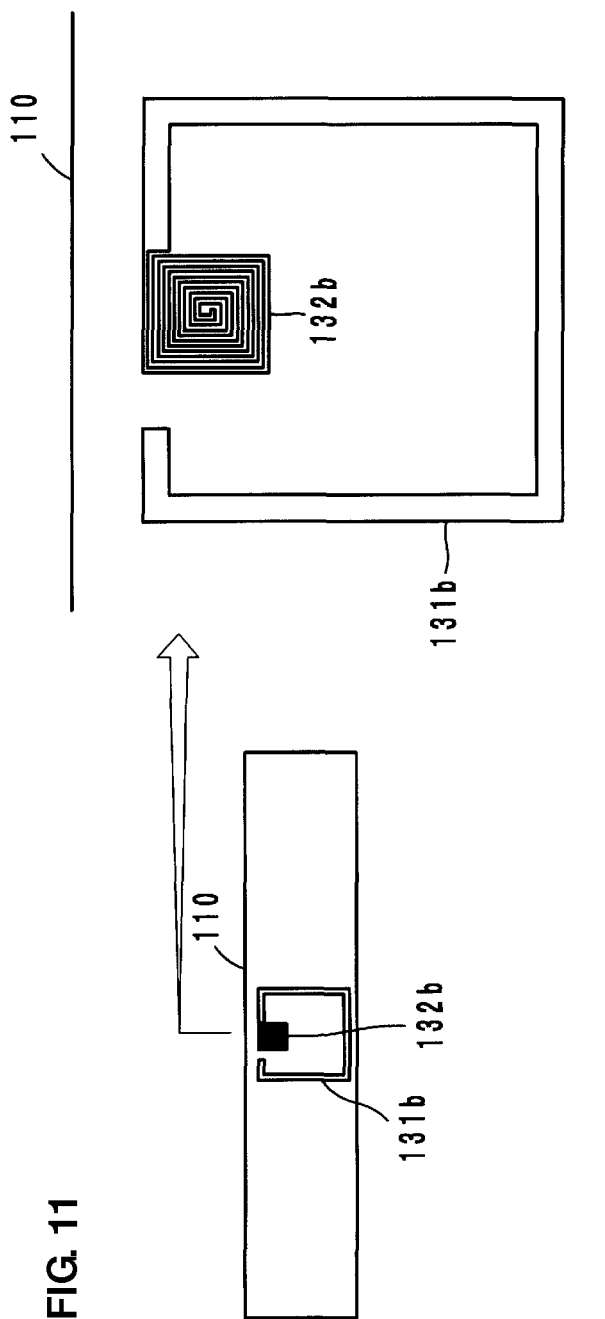


FIG. 12

125

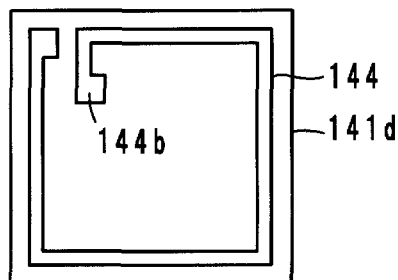
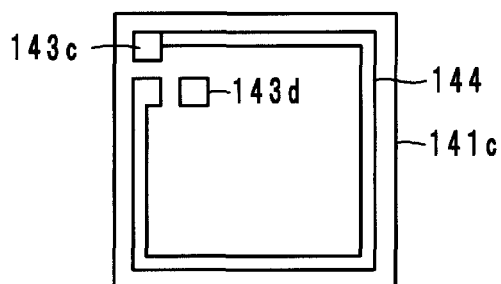
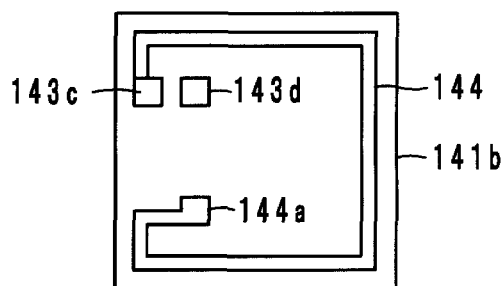
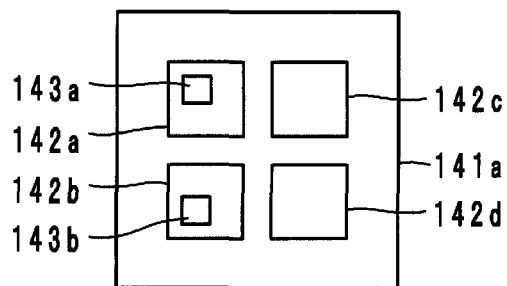


FIG. 13

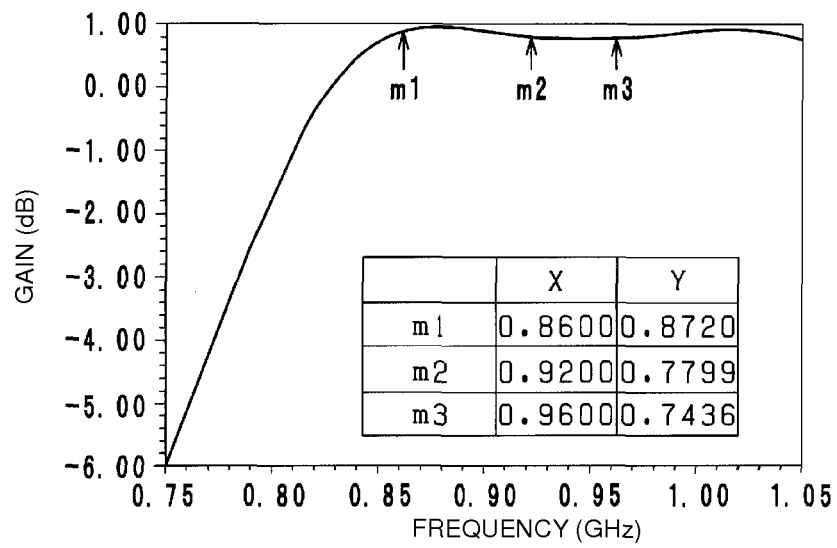
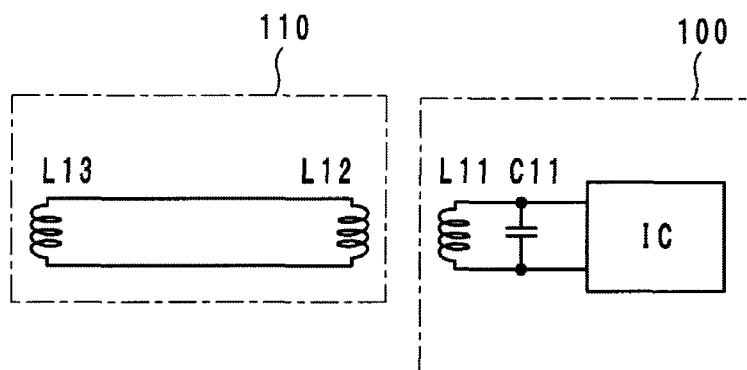


FIG. 14
PRIOR ART



ANTENNA AND WIRELESS IC DEVICE

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an antenna and a wireless IC device, and more particularly, to an antenna for a wireless IC device used in an RFID (Radio Frequency Identification) system and a wireless IC device including the antenna.

2. Description of the Related Art

In general, RFID systems in which a reader/writer that generates an electromagnetic wave and a wireless IC (referred to as an IC tag, a wireless IC device, etc.) that is attached on an article, a container or other suitable object and stores predetermined information communicate with each other in a non-contact manner to transfer information have been developed as a management system for articles. Communication with the reader/writer is achieved by coupling the wireless IC with an antenna (emission plate).

As a wireless IC of this type, Japanese Unexamined Patent Application Publication No. 10-293828 describes a wireless IC in which a coil L11 of an ID module 100 and a coil L12 of an antenna module 110 are coupled and set to resonate at a predetermined frequency, as shown in FIG. 14. The ID module 100 causes the primary coil L11 and a capacitor C11 to produce parallel resonance. The antenna module 110 is configured to have a closed loop by electrically connecting the ends of two coils L12 and L13 to each other. Energy is transferred between the two coils L12 and L13 by a current. That is, a magnetic field is emitted when the current, which is generated by the coil L12 coupled with the primary coil L11, passes through the coil L13.

However, increasing the inductance value of the coil for emission L13 and decreasing the inductance value of the coupling coil L12 in order to increase the magnetic field energy to be received from the reader/writer causes the voltage at the ends of the coil L12 to decrease. Therefore, there is a problem in that the amount of current flowing between the two coils L12 and L13 is decreased and sufficient energy is not transferred from the IC to the coil for emission L13, which reduces the communication distance. In addition, when the emission coil L13 is close to the antenna of the reader/writer or is close to another wireless IC, the inductance value varies due to the mutual inductance and the resonant frequency of the primary coil L11 also varies. As a result, reading by the reader/writer may be disabled.

SUMMARY OF THE INVENTION

To overcome the problems described above, preferred embodiments of the present invention provide an antenna for a wireless IC device having improved energy transfer efficiency with a wireless IC, and a wireless IC device including the antenna.

An antenna according to a preferred embodiment of the present invention preferably includes an antenna pattern, and spiral coupling patterns coupled to the antenna pattern and arranged so as to face each other.

A wireless IC device according to another preferred embodiment of the present invention preferably includes an antenna pattern, spiral coupling patterns coupled to the antenna pattern and arranged so as to face each other, and a coupling module including a wireless IC and a feeder circuit substrate including a feeder circuit arranged to be coupled to the wireless IC, wherein the feeder circuit includes an inductor, and the coupling module is mounted on the coupling patterns.

In the antenna and the wireless IC device, the spiral coupling patterns coupled to the antenna pattern preferably are arranged so as to face each other to define a single LC resonator. That is, a capacitor is provided between the spiral coupling patterns arranged so as to face each other, and LC resonance is obtained by using the capacitor and inductances produced by the spiral coupling patterns. This LC resonance increases the impedance to infinity, whereby energy is concentrated in the coupling patterns. As a result, energy transfer efficiency between the antenna and the wireless IC mounted thereon is improved.

In the antenna and the wireless IC device, the antenna pattern may preferably be a single coil pattern, two coil patterns arranged so as to face each other, or two circular patterns including at least a pair of ends and arranged so as to face each other, and may preferably include a dipole-type emitter coupled to the circular patterns, for example. In particular, more magnetic fields can be generated when two layers of antenna patterns are arranged so as to face each other. In addition, when the antenna patterns, which are arranged in a pair, are coupled to each other and the coupling patterns, which are arranged in a pair, are coupled to each other, stray capacitance is prevented from occurring between the patterns even when multiple wireless IC devices are close thereto or a dielectric, such as a human hand, is close thereto, thereby preventing resonant frequency variations.

According to various preferred embodiments of the present invention, the transfer efficiency between the antenna and the wireless IC is greatly improved and energy can be efficiently transferred.

The above and other elements, features, steps, characteristics, and advantages of the present invention will become more apparent from the following detailed description of the preferred embodiments with reference to the attached drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a sectional view illustrating a wireless IC device according to a first preferred embodiment of the present invention.

FIG. 2 is a perspective view illustrating main components of the wireless IC device according to the first preferred embodiment of the present invention.

FIG. 3 is a perspective view illustrating enlarged coupling patterns of the wireless IC device according to the first preferred embodiment of the present invention.

FIG. 4 is a plan view illustrating a disassembled layered structure of a feeder circuit substrate to be mounted on the wireless IC device according to the first preferred embodiment of the present invention.

FIG. 5 is a perspective view illustrating main components of a wireless IC device according to a second preferred embodiment of the present invention.

FIG. 6 is a plan view illustrating enlarged coupling patterns of the wireless IC device according to the second preferred embodiment of the present invention.

FIG. 7 is an equivalent circuit diagram of an antenna according to the first preferred embodiment of the present invention.

FIG. 8 is an equivalent circuit diagram of an antenna according to the second preferred embodiment of the present invention.

FIG. 9 is a plan view of a wireless IC device according to a third preferred embodiment of the present invention.

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FIG. 10 is a plan view of an antenna pattern arranged on the front surface side of the wireless IC device according to the third preferred embodiment of the present invention.

FIG. 11 is a plan view of an antenna pattern arranged on the back surface side of the wireless IC device according to the third preferred embodiment of the present invention.

FIG. 12 is a plan view illustrating a disassembled layered structure of a feeder circuit substrate mounted on the wireless IC device according to the third preferred embodiment of the present invention.

FIG. 13 is a graph illustrating the gain of the wireless IC device according to the third preferred embodiment of the present invention.

FIG. 14 is an equivalent circuit diagram illustrating a conventional example of a wireless IC device.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

An antenna and a wireless IC device according to preferred embodiments of the present invention will be described below with reference to the accompanying drawings. Note that common reference signs are used to denote the same members and sections in the drawings, and duplicate explanation is omitted.

First Preferred Embodiment

A wireless IC device 1A according to a first preferred embodiment of the present invention preferably includes a substrate 10, a coupling module 20, and an antenna 30, as shown in FIGS. 1 and 2. The coupling module 20 includes a wireless IC chip 21 and a feeder circuit substrate 25 including a feeder circuit arranged to be coupled to the wireless IC chip 21. The antenna 30 includes a coil pattern 31 and spiral coupling patterns 32a and 32b that are provided at the ends of the coil pattern 31 and arranged so as to face each other.

The substrate 10 is preferably made of a dielectric, such as a PET film, for example. The coil pattern 31 preferably has a coil shape on the front surface of the substrate 10, as shown in FIG. 2. The spiral coupling pattern 32a is provided at one end thereof. The spiral coupling pattern 32b is arranged on the back surface of the substrate 10 so as to face the coupling pattern 32a. An end 32c of the coupling pattern 32b is electrically connected to the other end 31c of the coil pattern 31 through a via hole conductor 33.

The wireless IC chip 21 includes a clock circuit, a logic circuit, a memory circuit, and other suitable circuits, as is known in the art, and necessary information is stored therein. The wireless IC chip 21 includes an input terminal electrode, an output terminal electrode, and mounting terminal electrodes, which are not shown. The feeder circuit substrate 25 is preferably, as described below with reference to FIG. 4, a layered substrate in which the feeder circuit including an inductor is embedded, and mounted (bonded) on the coupling pattern 32a. Note that, although the coupling module 20 includes the wireless IC chip 21 and the feeder circuit substrate 25 that are separately provided, a wireless IC and a feeder circuit may be integrally provided on a single substrate.

An example of the feeder circuit embedded in the feeder circuit substrate 25 will be described with reference to FIG. 4. The feeder circuit substrate 25 preferably includes a plurality of layered sheets 41a to 41g including electrodes provided thereon. Each of the sheets 41a to 41g is preferably made of ceramic or resin, for example.

Electrodes 42a to 42d are provided on and via hole conductors 43a and 43b extend through the sheet 41a. An elec-

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trode 44 is provided on and via hole conductors 43c and 43d extend through the sheets 41b to 41f. An electrode 44 is provided on the sheet 41g.

When the sheets 41a to 41g are layered, the electrodes 44 of the sheets are electrically connected together through the via hole conductor 43d, thereby forming an inductor. One end of the inductor (an end 44a of the electrode 44 on the sheet 41b) is connected to the electrode 42b on the sheet 41a through the via hole conductor 43b. The other end of the inductor (an end 44b of the electrode 44 on the sheet 41g) is connected to the electrode 42a on the sheet 41a through the via hole conductors 43c and 43a. The inductor resonates at a predetermined resonant frequency with the inductance thereof and the capacitance between lines of the electrode 44.

The electrodes 42a and 42b on the sheet 41a are connected to the input terminal electrode and the output terminal electrode, respectively, of the wireless IC chip 21. The electrodes 42c and 42d on the sheet 41a are connected to the mounting terminal electrodes of the wireless IC chip 21. In addition, the inductor is magnetically coupled to the coupling patterns 32a and 32b.

In the wireless IC device 1A, a high-frequency signal, for example, a UHF frequency band or an HF frequency band, emitted from the reader/writer is received by the coil pattern 31, and the feeder circuit magnetically coupled to the coupling patterns 32a and 32b is resonated to feed only a reception signal of a predetermined frequency to the wireless IC chip 21. The wireless IC chip 21 extracts a predetermined energy from the reception signal and reads the stored information using the energy as a driving source. After being matched to a predetermined frequency in the feeder circuit, the energy is emitted from the coil pattern 31 as a transmission signal through the coupling patterns 32a and 32b and transmitted to the reader/writer.

The coil pattern 31 is preferably an open type coil pattern. The coupling patterns 32a and 32b disposed at the ends of the coil pattern 31 are arranged close to each other and define an LC resonator (see FIG. 7). That is, a capacitor C is provided between the spiral coupling patterns 32a and 32b arranged so as to face each other, and LC resonance is obtained using the capacitor C and the inductances L1 and L2 provided by the spiral coupling patterns 32a and 32b. This LC resonance increases the impedance to infinity, whereby energy is concentrated in the coupling patterns 32a and 32b. As a result, the energy transfer efficiency between the antenna 30 and the wireless IC chip 21 mounted thereon is significantly improved. In addition, since the two facing coupling patterns 32a and 32b are wound from the center in opposite directions in plan view, the directions of current flow are the same. Therefore, the directions of magnetic field are matched, and the degree of coupling is improved.

Further, the resonant frequency of the feeder circuit substantially corresponds to the resonant frequency of the reception/transmission signal. That is, the resonant frequency of the resonance circuit determines the resonant frequency of the wireless IC device 1A. Therefore, communication can be performed at the resonant frequency of the resonance circuit independent of the resonant frequency of the coil pattern 31, and, thus, a combination of one type of antenna 30 and the feeder circuit substrate 25 having various resonant frequencies is enabled. In addition, since the effects from other objects will not change the resonant frequency of the resonance circuit, a stable communication with the reader/writer is obtained.

The resonant frequency of the coil pattern 31 is preferably set to be higher than the resonant frequency of the resonance circuit included in the feeder circuit substrate 25. For

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example, when the resonant frequency of the feeder circuit is about 13.56 MHz, the resonant frequency of the coil pattern is preferably set to about 14 MHz. This causes the feeder circuit and the coil pattern **31** to be magnetically coupled at all times. For the antenna **30**, the communication distance is large when the resonant frequency thereof is close to the resonant frequency of the resonance circuit. However, when a communication failure caused by another wireless IC device or a dielectric, such as a human hand, comes close to the antenna **30** is considered, it is preferable that the resonant frequency of the coil pattern **31** is set to be on the higher frequency side.

Furthermore, since the coupling patterns **32a** and **32b** are preferably disposed directly under the magnetic field emitted from the feeder circuit substrate **25**, and the inductor in the feeder circuit substrate **25** preferably has a spiral shape so that the current flows in the same direction as the coupling patterns **32a** and **32b** (the direction of the current flowing in the inductor is shown as direction A in FIG. 4, and the direction of the currents flowing in the coupling patterns **32a** and **32b** is shown as direction B in FIG. 3), energy can be transferred more efficiently.

Although the wireless IC chip **21** and the feeder circuit substrate **25** are preferably electrically connected to each other, it is sufficient that the feeder circuit substrate and the antenna **30** are bonded to one another using an insulating adhesive agent, for example. Since bonding can be achieved in any direction and the area of the coupling patterns **32a** and **32b** is greater than the area of the feeder circuit substrate **25**, positioning is extremely easy when the coupling module **20** is mounted on the coupling pattern **32a**.

The feeder circuit substrate **25** is preferably made of a material including a magnetic substance, for example. The Q value is relatively high even when the embedded inductor is small, and thus, the size of the feeder circuit substrate **25** can be reduced. When the feeder circuit substrate **25** includes a plurality of layers, the magnetic permeability of the layer at the side of the surface that is mounted on the coupling pattern **32a** is preferably relatively small (for example, using a non-magnetic layer). With a small magnetic permeability, a magnetic field is easily generated at an adjacent exterior portion, whereby a coupling force is increased only with the coupling patterns **32a** and **32b**, and thus, interference caused by other objects is prevented.

Second Preferred Embodiment

A wireless IC device **1B** according to a second preferred embodiment of the present invention preferably includes a substrate that is substantially the same as the substrate **10** of the first preferred embodiment, which is not shown, the coupling module **20** and an antenna **50** shown in FIG. 5. The antenna **50** preferably includes two coil patterns **51a** and **51b** arranged on the front surface and the back surface, respectively, of the substrate so as to face each other, and spiral coupling patterns **52a** and **52b** provided at one end of the respective coil patterns **51a** and **51b** and arranged so as to face each other. The coupling module **20** is preferably substantially the same as in the first preferred embodiment and is mounted (bonded) on the coupling pattern **52a**. The communication configuration between the wireless IC device **1B** and the reader/writer is preferably substantially the same as that in the first preferred embodiment.

Also in the wireless IC device **1B**, the coil patterns **51a** and **51b** are preferably open type coil patterns. A capacitor C is provided between the coil patterns **51a** and **51b** and between the spiral coupling patterns **52a** and **52b**, which are arranged so as to face each other, and LC resonance is obtained by the capacitor C and the inductances L1 and L2 defined by the two coil patterns **51a** and **51b** and the spiral coupling patterns **52a**

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and **52b** (see FIG. 8). The LC resonance increases the impedance to infinity, whereby energy is concentrated in the coil patterns **51a** and **51b** and the coupling patterns **52a** and **52b**. As a result, energy transfer efficiency between the antenna **50** and the wireless IC chip **21** mounted thereon is significantly improved. In addition, since two layers of the coil patterns **51a** and **51b** are provided, more magnetic fields are generated. Furthermore, since the coil patterns **51a** and **51b**, which are arranged in a pair, are coupled to each other and the coupling patterns **52a** and **52b**, which are arranged in a pair, are coupled to each other, stray capacitance is prevented from occurring between the patterns even when multiple wireless IC devices are close thereto or a dielectric, such as a human hand, is close thereto, thereby preventing resonant frequency variation. Other effects and advantages achieved by the second preferred embodiment are the same as those of the first preferred embodiment.

In the second preferred embodiment, the entire antenna **50** resonates at a predetermined frequency. Therefore, when the coupling module **20** is mounted on the coupling patterns **52a** and **52b**, which are defined by portions of the antenna **50**, the antenna **50** and the coupling module **20** are coupled only by magnetic field at a predetermined frequency. The antenna **50** and the reader/writer are coupled by electromagnetic field.

Third Preferred Embodiment

A wireless IC device **1C** according to a third preferred embodiment of the present invention preferably includes a substrate **110**, a coupling module **120**, and an antenna **130**, as shown in FIG. 9. The coupling module **120** preferably includes a wireless IC chip **21** and a feeder circuit substrate **125** including a feeder circuit arranged to be coupled to the wireless IC chip **21**.

The antenna **130** (the front surface side is shown in FIG. 10 and the back surface side is shown in FIG. 11) preferably includes two circular patterns **131a** and **131b** each having a pair of ends and arranged on the front surface and the back surface, respectively, of the substrate **110** so as to face each other, spiral coupling patterns **132a** and **132b** provided at one end of the respective circular patterns **131a** and **131b** and arranged so as to face each other, and two emitters **133** extending to the sides from a portion of the circular pattern **131a**. The emitters **133** are coupled to the circular pattern **131a** so as to function as a meandering dipole-type antenna.

An example of the feeder circuit embedded in the feeder circuit substrate **125** will be described with reference to FIG. 12. The feeder circuit substrate **125** preferably includes a plurality of sheets **141a** to **141d** including electrodes provided thereon. Each of the sheets **141a** to **141d** is preferably made of ceramic or resin, for example.

Electrodes **142a** to **142d** are provided on and via hole conductors **143a** and **143b** extend through the sheet **141a**. An electrode **144** is provided on and via hole conductors **143c** and **143d** extend through the sheets **141b** and **141c**. An electrode **144** is provided on the sheet **141d**.

When the sheets **141a** to **141d** are layered, the electrodes **144** of the sheets are electrically connected together through the via hole conductor **143c**, thereby forming an inductor. One end of the inductor (an end **144a** of the electrode **144** on the sheet **141b**) is connected to the electrode **142b** on the sheet **141a** through the via hole conductor **143b**. The other end of the inductor (an end **144b** of the electrode **144** on the sheet **141d**) is connected to the electrode **142a** on the sheet **141a** through the via hole conductors **143d** and **143a**. The inductor resonates at a predetermined resonant frequency with the inductance thereof and the capacitance between lines of the electrode **144**.

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The electrodes **142a** and **142b** on the sheet **141a** are connected to the input terminal electrode and the output terminal electrode, respectively, of the wireless IC chip **21**. The electrodes **142c** and **142d** on the sheet **141a** are connected to the terminal electrodes for mounting of the wireless IC chip **21**. In addition, the inductor is magnetically coupled to the coupling patterns **132a** and **132b**.

Also in the wireless IC device **1C**, which is the present third preferred embodiment, the circular patterns **131a** and **131b** in the wireless IC device **1C** are preferably open type circular patterns. Preferably, a capacitor **C** is provided between the circular patterns **131a** and **131b** and between the spiral coupling patterns **132a** and **132b**, which are arranged so as to face each other, and LC resonance is obtained by the capacitor **C** and the inductances **L1** and **L2** defined by the two circular patterns **131a** and **131b** and the spiral coupling patterns **132a** and **132b**. That is, the same equivalent circuit as in FIG. **8** is provided. This LC resonance increases the impedance to infinity, whereby energy is concentrated in the circular patterns **131a** and **131b** and the coupling patterns **132a** and **132b**. As a result, energy transfer efficiency between the antenna **130** and the wireless IC chip **21** mounted thereon is significantly improved. Consequently, a high frequency signal is efficiently emitted from the emitters **133**, and a high frequency signal received by the emitters **133** is efficiently transferred to the feeder circuit. In the wireless IC device **1C** according to the third preferred embodiment, the circular patterns **131a** and **131b** are arranged so as to couple to the feeder circuit and the emitters **133**, whereby the loss of a signal transferred to the emitters **133** is reduced and a high gain is obtained. The gain of the wireless IC device **1C** against frequency of a high frequency signal is illustrated as in FIG. **13**. A high gain is achieved in a UHF frequency band.

Regarding the gain, a wider bandwidth can be obtained by changing the position of coupling points **K** (see FIG. **9**) of the circular pattern **131a** and the emitters **133**. For example, a wider bandwidth can be obtained by moving the position of the coupling points **K** close to the coupling pattern **132a** to increase the inductance value between the coupling points **K**. This is because when the inductance value between the coupling points **K** is increased, the bandwidth between two resonance points provided by the emitters **133** is increased. Note that the circular pattern **131a** may preferably be replaced by a meander pattern or a spiral pattern, for example, in order to increase the inductance value between the coupling points **K**.

In addition, since two layers of the circular patterns **131a** and **131b** are provided, more magnetic fields can be generated. Furthermore, since the circular patterns **131a** and **131b**, which are preferably arranged in a pair, are coupled to each other and the coupling patterns **132a** and **132b**, which are preferably arranged in a pair, are coupled to each other, stray capacitance is prevented from occurring between the patterns even when multiple wireless IC devices come close thereto or a dielectric, such as a human hand, comes close thereto, thereby preventing resonant frequency variations. Other effects and advantages achieved by the third preferred embodiment are the same as those of the first preferred embodiment.

In addition, in the third preferred embodiment, the entire antenna **130** resonates preferably at a predetermined frequency. Therefore, when the coupling module **120** is mounted on the coupling patterns **132a** and **132b**, which are defined by portions of the antenna **130**, the antenna **130** and the coupling module **120** are coupled only by magnetic field at a predetermined frequency. The antenna **130** and the reader/writer are coupled by electromagnetic field.

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The antenna and the wireless IC device according to the present invention are not limited to the foregoing preferred embodiments.

As described above, preferred embodiments of the present invention are useful in antennas and wireless IC devices used in RFID systems. In particular, preferred embodiments of the present invention are superior in terms of the energy transfer efficiency with a wireless IC.

While preferred embodiments of the present invention have been described above, it is to be understood that variations and modifications will be apparent to those skilled in the art without departing from the scope and spirit of the present invention. The scope of the present invention, therefore, is to be determined solely by the following claims.

What is claimed is:

1. A wireless IC device comprising:

a substrate including first and second surfaces that are opposed to each other;

first and second antenna patterns respectively arranged on the first and second surfaces of the substrate so as to face each other, and each including first and second ends;

first and second coupling patterns respectively arranged on the first and second surfaces of the substrate so as to face each other;

a wireless IC; and

a feeder circuit including an inductor arranged to be connected to the wireless IC; wherein

one end of the first coupling pattern is connected to the first end of the first antenna pattern and another end of the first coupling pattern is open-ended;

one end of the second coupling pattern is connected to the first end of the second antenna pattern and another end of the second coupling pattern is open-ended;

the second end of each of the first and second antenna patterns is open-ended;

the first antenna pattern and the first coupling pattern are wound in the same direction on the first surface of the substrate;

the second antenna pattern and the second coupling pattern are wound in the same direction on the second surface of the substrate;

the first and second coupling patterns are located inside of the first and second antenna patterns in plan view, and provide both capacitive coupling and magnetic-field coupling; and

the inductor of the feeder circuit is magnetically coupled to both of the first and second coupling patterns.

2. The wireless IC device according to claim 1, wherein the first and second antenna patterns are defined by coil-shaped patterns arranged so as to face each other.

3. The wireless IC device according to claim 1, wherein the inductor has a spiral shape such that current flows in the same direction as the first and second coupling patterns.

4. The wireless IC device according to claim 1, wherein a resonant frequency of the feeder circuit substantially corresponds to a resonant frequency of a reception/transmission signal.

5. The wireless IC device according to claim 1, wherein a resonant frequency of the coil-shaped antenna pattern is higher than a resonant frequency of the feeder circuit.

6. The wireless IC device according to claim 1, further comprising:

a feeder circuit substrate on which the feeder circuit is disposed; wherein

an area of the coupling patterns is greater than an area of the feeder circuit substrate.

7. The wireless IC device according to claim 1, further comprising:

a feeder circuit substrate on which the feeder circuit is disposed; wherein

the feeder circuit substrate is made of a material including a magnetic substance. 5

8. The wireless IC device according to claim 7, wherein the feeder circuit substrate includes a plurality of layers and a magnetic permeability of a layer of the plurality of layers at a side of a surface that is mounted on the first and second 10 coupling patterns is smaller than at least one other layer of the plurality of layers.

* * * * *